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Abstract

Introduction

Freezing of gait (FOG) in Parkinson's disease (PD) is associated with an altered posture during quiet stance as well as an impaired preparation and execution of the gait initiation process. We aimed to investigate whether an altered initial posture impacts anticipatory postural adjustments (APAs) and first-step execution during gait initiation in people with PD with FOG (PD+FOG).

Methods

Twenty-seven PD+FOG, 30 PD patients without FOG and 27 age-matched healthy controls performed self-generated gait initiation. Initial mean center of pressure (COP) position prior to APA onset, characteristics of APAs and features of first-step execution were investigated.

Results

Contrarily to controls, PD patients showed a COP that was initially positioned more towards the stance leg ($p = 0.007$). Moreover, significantly smaller backward COP shift, longer duration of swing-foot unloading phase, and lower first-step length and velocity characterized PD+FOG compared to controls. While size and duration of backward COP shift during APA and lateral COP shift during the unloading phase were main predictors of first-step length and velocity in all groups, the medio-lateral shift of the initial COP position in PD+FOG was a main predictor of first-step execution ($\beta = -0.191$, $p = 0.001$ for velocity).

Conclusion

In PD+FOG, the more the COP was initially positioned towards the stance foot, the slower and shorter the first step. The initial medio-lateral COP position may be a compensatory strategy to address postural instability of PD+FOG. A specific training regarding postural control prior to gait preparation and execution could improve functional mobility in PD+FOG.

Keywords: Postural control; anticipatory postural adjustments (APAs); gait initiation; Parkinson's disease (PD); freezing of gait (FOG)

Background and aim

Occurring in about 80 % of people with Parkinson's disease (PD) in the later stages of the disease [1], freezing of gait (FOG) is a paroxysmal axial symptom that is usually described as a "brief, episodic absence or marked reduction of forward progression of the feet despite the intention to walk" [2]. While the underlying pathophysiological mechanisms are still not fully understood, several hypotheses have been proposed. Among them, abnormal coupling of posture with gait was suggested [3], based for example on the observation of an increased head-pelvis coupling during turning in PD patients with FOG (PD+FOG) [4].

However, the relationship between FOG and postural control seems complex. PD+FOG present worse postural control in comparison with PD patients without FOG (PD-FOG) [5], particularly regarding dynamic postural control and anticipatory postural adjustments (APAs) preceding gait (for a review, see [6]). Motor timing impairments and reduced flexibility to shift between motor strategies in PD+FOG might lead to or be the consequence of a dysfunctional uncoupling of the center of pressure (COP) and the center of mass (COM) during preparation of forward progression [7]. This impaired uncoupling can also be seen as a protective strategy to attenuate the postural demand on preparatory movement. FOG has thus been related to poor spatio-temporal characteristics of APAs [8,9], and even impaired coupling between preparation and execution of gait [10,11].

Postural control during quiet stance was also found to be different in PD+FOG compared to PD-FOG [6,12,13]. In a previous study [14], in contrast to PD-FOG and healthy controls (HC), PD+FOG presented a shift of their mean COP position towards the heels and this COP displacement was positively correlated to FOG severity. It remains unclear whether this altered COP position during quiet stance might contribute to the abnormal coupling between APAs and the step motor program and might thus be a possible cause for the occurrence of start hesitation in PD+FOG.

The present study aims to investigate the impact of the initial posture during stance prior to APA onset on first-step preparation and execution, and on their coupling in PD+FOG.

Methods

Participants

People with PD and HC were included in this study. PD was diagnosed according to the UK Brain Bank criteria. The group of PD+FOG was composed of patients with an unambiguous previous history of FOG, reported through the third item of the Freezing of Gait Questionnaire and the observation of overt FOG episodes during a specific gait trajectory that was thought to trigger FOG (i.e., pathway including gait initiation and stopping, rapid 360° and 540° turns, a narrow passage and dual tasking) [15]. Exclusion criteria were cognitive impairment (i.e., Mini Mental State Examination or MMSE score < 24), other causes of gait disorders, major psychiatric disorders or severe co-morbidities. PD patients were tested in the ON-state of medication. The study was approved by the ethical committee and a written informed consent was signed by all the participants prior to their participation. Data came in part from [11].

Task

Participants were standing centrally on a force platform, with their feet parallel and in a stance width that was comfortable and natural to them. The investigator then gave a precise instruction: "When

you are ready, start to walk as fast as possible and with the starting foot of your choice", while checking that the subjects did not start immediately after this instruction. After four or five steps, participants were asked to stop by the examiner. Videos of the trials were rated by two independent assessors to evaluate whether actual FOG events occurred or not.

Material

Two force platforms (the OR6 from AMTI, Waterton, USA) and a video motion analysis system (VICON from Oxford Metrics Ltd., Oxford, UK) equipped with 6 infrared cameras were used to assess kinetic, but also kinematic measurements of gait initiation. Both systems were synchronized: the force platforms with a sampling rate of 250 Hz, and the VICON system with a video sampling frequency of 50 Hz. Six spherical, retroreflective markers of 2.5 cm in diameter were placed bilaterally on the lateral malleoli, the heels, and the head of second metatarsals.

Kinetic and kinematic data analysis

In order to assess preparation and execution of gait, different spatio-temporal features of the first step were extracted from the data, by using an in-house MATLAB script (The MathWorks, Natick, MA, USA) based on methodologies found in the literature to detect gait events [16–19]. Data of each trial were plotted and visually checked. Studied parameters were stance width, initial mean anterior-posterior (AP) and medio-lateral (ML) COP positions (averaged over 1 s prior to APA onset and expressed respectively as percentage of foot length and stance width), APA onset (T_0), duration of APA, AP and ML sizes of APA, duration (T_U) and lateral COP shift (COP_U) during the swing-foot unloading phase, swing phase duration, and length and velocity of first step. Details of calculation of such features are illustrated in Figures 1 and A.1 and detailed in Supplementary material file.

Clinical measures

The MMSE was conducted to evaluate cognition. For patients with PD, disease severity was assessed with the Unified Parkinson's Disease Rating Scale part III; disease duration was also reported.

Statistical analysis

Demographic and clinical data between PD+FOG, PD-FOG and HC were compared with Kruskal-Wallis test, and between PD+FOG and PD-FOG with Mann-Whitney U test. Dichotomous data were compared using Chi-Square test.

As data were initially recorded in a different context, some participants' trials were thus not preceded by a quiet stance of at least 1 s and excluded, leading to a median amount of trials (first quartile – third quartile) of 3 (3 – 4), 4 (3 – 5) and 3 (2 – 4) for PD+FOG, PD-FOG and HC, respectively. Because a different amount of trials was available for each participant, differences between groups in terms of initial mean COP position and characteristics of the first-step preparation (features of APA) and execution (the step itself) were statistically tested using a linear mixed model with group as fixed effect, participant as random effect and stance width as covariate (except for the analysis of the initial mean ML COP position). In order to control for a significantly different clinical variable between PD groups (i.e. disease duration), a second ANCOVA related to the PD patients only was carried out. A Tukey correction for post-hoc tests was used to adjust for multiple comparisons. When the assumptions of normal distribution and homoscedasticity of residuals among groups were violated, generalized linear mixed models were used.

Furthermore, in order to investigate the relationships between the initial mean COP position, gait preparation and first-step execution in each group, repeated measures correlation coefficients were assessed and allowed to determine the common within-individual association for paired measures evaluated in a given population. Based on that, different linear mixed models including uncorrelated features of quiet stance prior to gait initiation and characteristics of APAs as potential predictors of first-step length and velocity were the starting point for choosing the best regression model associated with each group by Akaike's Information Criteria in a backward stepwise algorithm. Disease duration was also tested as an independent variable in the regression analysis related to each PD group.

All statistical analyses were conducted in R [20], and the statistical significance threshold was $p < 0.05$. More details are reported in Supplementary material file.

Results

Subjects

Twenty-seven PD+FOG, 30 PD-FOG and 27 HC were included. The three groups were well balanced for age, gender, height, cognition and disease severity for PD patients (Table 1). PD+FOG had significantly longer disease duration than PD-FOG. On average, three (between one and five) consecutive trials were recorded for each participant, with a period of quiet stance just before APA onset related to the initiation of the first step. Subtle FOG events during gait initiation in PD+FOG were observed in n=19 out of n=87 trials. We did not differentiate this kind of trials from others because complementary analyses (see supplementary material online) demonstrated that excluding trials with a FOG episode did not change the results obtained with all gait trials.

People with PD showed altered initial COP position prior to gait initiation in ML direction

A significant group effect was found for the initial mean ML COP position: PD patients had a COP initially positioned towards the stance leg whereas controls' COP was rather located towards the swing leg. Besides, when controlling for disease duration, a significantly more posterior initial mean COP position was found for PD-FOG compared to PD+FOG (Table 1 and Figure 2). This means that PD-FOG in later stages of the disease would have shown a COP prior to gait initiation positioned significantly more backwards than PD+FOG. Moreover, initial stance width was significantly larger in PD+FOG compared to PD-FOG, but this difference was not significant anymore when controlling for disease duration.

Regarding first-step preparation and execution, PD+FOG presented a significantly lower backward COP displacement than HC, and any difference with PD-FOG was not observed anymore after considering disease duration as covariate. When controlling for stance width, there was no significant group effect for COP_U. Furthermore, despite similar duration of APAs across groups, PD+FOG took longer for unloading the swing foot and moving their COP towards the stance leg than PD-FOG and HC. Finally, PD+FOG showed significantly smaller first-step length and velocity than HC, whereas taking into account the difference in disease duration between the two PD groups did not reveal any significant differences between them (Table 1 and Figure C.1 in the Supplementary material section). Swing phase duration did not differ between populations.

Initial mean COP position prior to gait initiation predicted first-step length and velocity in individuals with PD

After the exclusion of correlated parameters of quiet stance, gait preparation and execution in all groups (Table D.1), regression analysis showed that, for all the participants, a fast first step was the consequence of a large backward COP shift during APA (see Table 2). Moreover, for people with PD, a fast first step was also explained in part by a great COP_U or by a large stance width, both being highly significantly correlated. Particularly for PD+FOG, a COP initially located closer to the swing foot and positioned more towards posterior was also part of the causes for a fast first step. In PD-FOG, a shorter T_U was found to be a significant predictor for a first step of high velocity.

Concerning first-step length, an initial mean COP position towards posterior and a great COP_U (stance width as equivalent in PD-FOG) were main predictors for a large first-step length in people with PD. In PD+FOG, an initial mean COP position towards the swing foot was also significantly associated with a first step of long length. Besides, within PD-FOG, a large backward COP shift during APA allowed to partly explain a long first step, as in the case of first-step velocity. Finally, HC seemed to take time for completing the unloading phase in order to initiate a first step of long length.

Discussion

To the best of our knowledge this is the first study investigating the impact of the initial COP position relative to the feet prior to APA onset on the preparation and execution of the gait initiation process and on their coupling in PD+FOG, even if previously explored in HC [21].

Among all groups, a large backward COP displacement during APA allowed to perform a step rapidly, thanks to a subsequent efficient forward propulsion of the COM (similar to what have been previously found in [22]). Moreover, within our participants with PD, ML COP excursion (the stance width or COP_U, by extension) was used to control the length and velocity of first step. Contrary to Brenière and colleagues' findings [22], longer APAs were not correlated to high velocity of first step because they are often the consequence of multiple APAs [11]. Such APAs can be deleterious for first-step velocity. In this context, T_U seems more interesting to analyze: it helps to control first-step length in HC and velocity of first step in PD-FOG. The significantly longer T_U in PD+FOG compared to the other groups might consist in a balance strategy along the ML axis, reinforcing the strategy of the initial ML COP position towards the stance foot (detailed below). In fact, similarly to healthy older adult fallers in comparison with non-fallers [23], for a comparable ML COP excursion during the swing-foot unloading phase, a longer duration of this phase would imply that the COP stays lateral to the COM for a longer time in PD+FOG. Consequently, a more efficient torque would propel the COM towards the stance foot, increasing the margin of stability at foot off and therefore, reducing the ML instability.

We found an initial mean ML COP position which was significantly positioned towards the stance leg in people with PD compared to HC. Regression analysis revealed that, in PD+FOG, the more the COP was shifted towards the stance leg prior to APA onset, the smaller and slower the first step. This may therefore partly explain why PD+FOG often perform small and slow first steps during the gait initiation process as often reported [24]. More specifically, the ML displacement of the COP towards the swing limb during APAs, by increasing the component of the ground reaction force towards the stance limb over a period of time, generates a momentum in this direction and consequently, a shift of the COM towards the stance leg. This ML shift of the COM aims in turn to provide postural stability during gait execution: it reduces the gap between the COP and COM at the time of toe off and thus attenuates the induced body disequilibrium and fall towards the swing leg [25]. By initially positioning the COP

(and therefore the COM which is "tracked" by the COP [26], both vertical projections being aligned during stable quiet stance) more towards the stance leg while showing similar ML size of APA and therefore the same momentum compared to HC, PD patients displaced their COM closer to the support leg at the time of foot off. They thus showed a smaller gap between COP and COM, attenuating the ML fall of the COM towards the swing leg due to gravity during the execution phase. This specific initial mean COP position in PD patients might reflect postural instability, since a short COP-COM distance during the locomotor phase of gait initiation would be related to impaired postural control [27,28]. Indeed, it might mirror a safe strategy regarding balance in the ML direction, an inability to generate adequate momentum using COP shifts in order to dynamically control the COM towards the stance leg, or a combination of both. This conservative initial COP position can in turn lead to poorer performance of first-step execution.

With respect to the AP direction, a previous study which investigated the COP position relative to the feet during quiet stance found a shift of the COP towards the heels in PD+FOG compared to PD-FOG and HC [14]. This may either compromise the ability to create propulsive forces (and therefore impair the step initiation process) or may be a compensatory mechanism to avoid forward falls. As we rather found a COP displacement towards anterior in PD+FOG right before APA onset, the results of the present study give a hint that the altered mean COP position relative to feet during quiet stance (without any intention to start walking) may play a minor role for the occurrence of start hesitation. It seems to be more relevant to study postural control just before preparation of gait in this population, even though a future study with recordings of both quiet stance and postural control prior to gait initiation should be performed to validate this suggestion.

Concerning the associations between initial COP position and performance of first step, results were not always consistent for PD+FOG and PD-FOG, indicating different mechanisms for these two subgroups. While positioning their COP initially more towards their stance leg compared to HC, PD-FOG might compensate this conservative strategy in ML direction by positioning their COP significantly more posteriorly than PD+FOG and reducing their basis of support with a decreased initial stance width. In this way, they were able to play with their initial AP COP position in order to generate a more or less large backward excursion of their COP during APAs and thus to compensate for their smaller amplitudes of APA as PD patients [29,30]. Indeed, it is more difficult to initiate a backward COP shift from an anterior COP position than from a more posterior location, since an AP unbalance towards forward before APA onset would not help the subsequent backward COP shift. In the end, this initial mean AP COP position seemed to have a higher impact on gait initiation than the conservative initial mean ML COP position and, consequently, AP size of APA was especially a good predictor of first-step length and velocity in PD-FOG. A shorter T_U also allowed to counteract the conservative initial ML COP position, allowing to increase first-step velocity.

Contrarily, PD+FOG also seemed to prioritize postural stability in ML direction but do not present the same compensatory strategy in AP direction during gait initiation. Indeed, their initial mean AP and ML COP positions were significant predictors of first-step length and velocity. A reason why the initial mean AP COP position is a better predictor of first-step execution than AP size of APA in PD+FOG, contrarily to PD-FOG, might be due to their more limited backward COP displacement during APAs. Therefore, the initial AP COP position prior to gait will represent a compensatory strategy for a better performance of first step. Indeed, for a given AP size of APA, the more posteriorly the COP starts its backward excursion, the smaller the AP margin of stability related to the heels at APA onset is, and thus the larger the initial AP disequilibrium is. This unbalance will help the subsequent backward COP shift for a more efficient forward COM displacement. However, the compensatory strategy of PD-FOG in AP direction seem to be more effective than the one of PD+FOG, since the conservative strategy in

ML direction keeps still a significant impact on characteristics of first step. Further, although the initial ML COP position prior to APA onset was not a significant predictor of FOG events (use of a mixed effects logistic regression model: odds ratio = 1.068, $p = 0.15$), it tended to be significantly positively correlated with the FOG trajectory score (Spearman's correlation: $R = 0.41$, $p = 0.053$).

Limits of the study were the mismatch of PD patients in terms of disease duration, and the short time interval prior to gait initiation not allowing to investigate the COP position during extended quiet stance. Furthermore, as we excluded patients with cognitive impairments, other gait disorders or severe comorbidities, the generalizability of our findings based on this more "pure sample" is limited. Given the link between FOG and medication cycles, future studies should be conducted in both, the ON and OFF state of medication. Moreover, as this study was purely observational, interventional studies should be conducted to further confirm our findings. Training weight shifting, or walking on a split-belt treadmill, is expected to improve postural control and it may especially ameliorate one leg stance ability; this may lead to a ML shift towards the swing foot prior APA, thus supporting our results.

Conclusion

People with PD showed a shift of the initial COP position prior to APA onset towards the stance foot, whereas HC initially placed their COP towards the swing foot. In PD+FOG, the more the COP was initially positioned towards the stance foot, the slower and shorter the first step. This characteristic initial ML COP position may be a compensatory strategy for addressing postural instability of PD+FOG. Whether PD+FOG may benefit from training altered initial posture prior to the gait initiation process should be investigated in future rehabilitation studies.

Declaration of interest

None.

Contributors

1) Research project: A. Conception, B. Data collection, C. Data analysis;
2) Statistical Analysis: A. Design, B. Execution, C. Review and critique;
3) Manuscript: A. Writing of the first draft, B. Review and critique.
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Legends

Figure 1. Determination of the mean AP and ML COP positions over 1 s prior to APA onset, expressed as a percentage of foot length and stance width, respectively. Crosses on the left = markers at left heel, malleolus and toe, and orthogonal projection of the middle point between left heel and toe markers on a parallel line passing by the marker at the left ankle; crosses on the right = markers at right heel, malleolus and toe, and orthogonal projection of the middle point between right heel and toe markers on a parallel line passing by the marker at the right ankle; crosses in the middle = middle points between heels and between toes; T_0 = APA onset; HO = heel off; TO = toe off; mCOP = mean COP position over 1 s prior to APA onset; SWF = swing foot; STF = stance foot

Table 1. Differences between groups in terms of demographic and clinical data, initial mean COP position prior to gait initiation, and characteristics of the preparation (APAs) and execution of the first step. For each group, the mean and standard deviation of gait and balance parameters averaged through each subject's trials were reported. The FOG trajectory was a standardized gait trajectory with the usual triggers of FOG: gait initiation and termination (self-triggered and cued), turning (360° and 540° turns in different directions, at preferred and maximal speed), narrow passages and dual tasks (walking and subtracting serials of three) [15]. During such trajectory, FOG severity was evaluated by the number and duration of FOG episodes (brief episodes of FOG < 10 s were rated 1, medium episodes between 10 and 30 s were rated 2, episodes > 30 s were rated 3). The FOG trajectory score was provided by two independent assessors. MMSE = Mini Mental State Examination; UPDRS III (Med ON) = Unified Parkinson's disease Rating Scale, part III, in the ON-state of medication; FOGQ = Freezing of Gait Questionnaire; NS = non-significant; * for p-value < 0.05; ** for p-value < 0.01; *** for p-value < 0.001

Figure 2. Characteristics of quiet stance and gait preparation that were significantly different between groups: (a) initial mean AP COP position over 1 s prior to APA onset (expressed as a percentage of foot length, starting from the mean distance between both heel markers (0%); (b) initial mean ML COP position over 1 s prior to APA onset (expressed as a percentage of stance width, starting from the swing leg (0%) towards the stance leg (100%)), dotted line represents the middle distance between stance and swing feet (50%); (c) AP size of APA; (d) unloading phase duration. SW = swing foot; ST = stance foot; # significant group difference between PD patients and controls (PD+FOG and PD-FOG > HC, with p-values < 0.05); * p-value of post-hoc tests < 0.05; ** p-value of post-hoc tests < 0.01; *** p-value of post-hoc tests < 0.001

Table 2. Backward stepwise multiple regressions for prediction of first step length and velocity in each group, with (linear mixed) models selection based on AIC. * for p-value < 0.05; ** for p-value < 0.01; *** for p-value < 0.001

Figures and tables

Figure 1

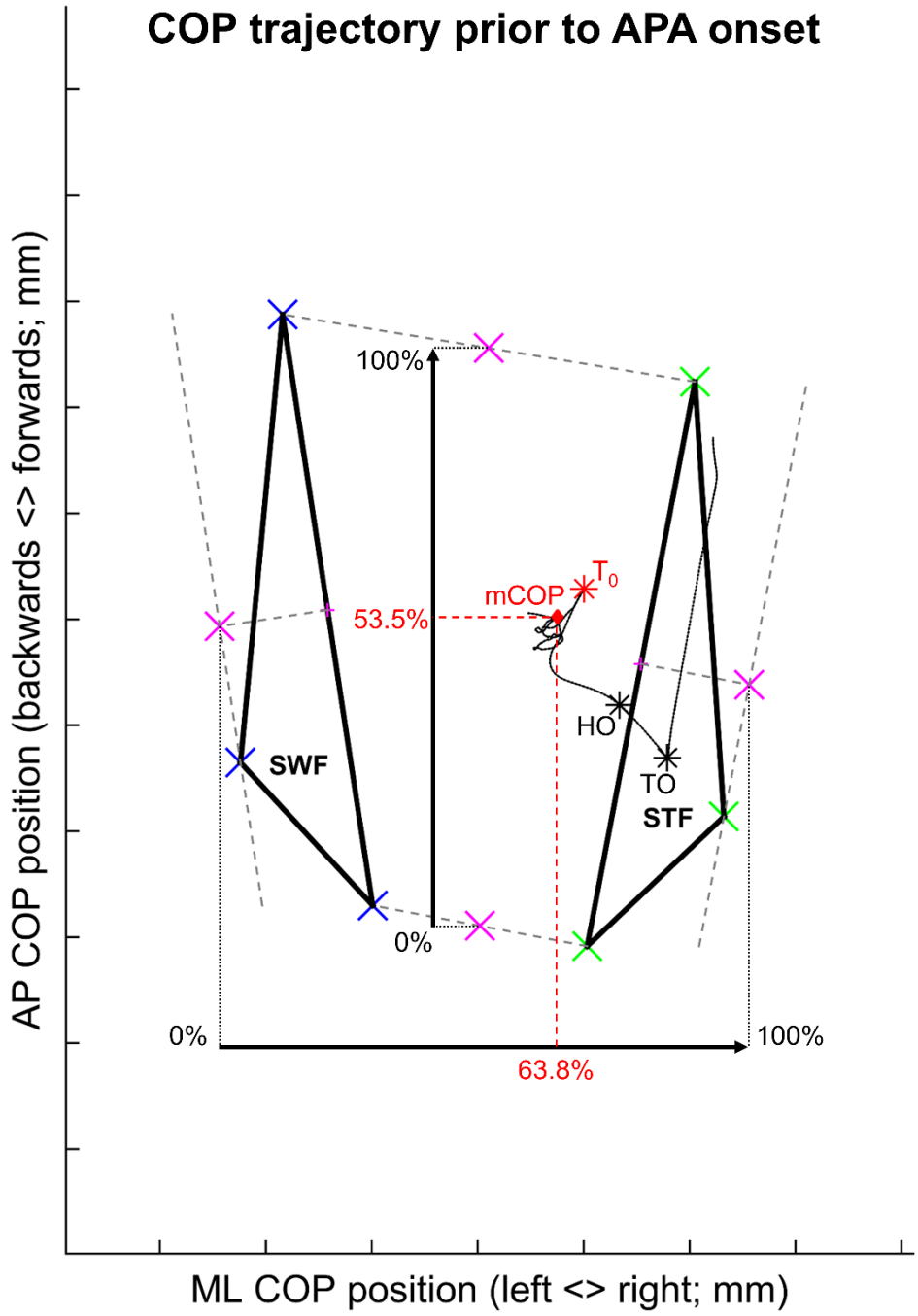

Table 1

Classification	Variable	PD+FOG (n=27) *Mean (SD)*	PD-FOG (n=30) *Mean (SD)*	HC (n=27) *Mean (SD)*	Effect of Group *(p-values)*	Post-hoc tests	Post-hoc tests when controlling for disease duration
Demographic and clinical data	**Age (years)**	64 (10.187)	64.633 (9.027)	61.346 (8.681)	0.407	/	/
	Gender (M/F)	15/12	19/11	12/15	0.358	/	
	Height (cm)	164.1 (9.629)	168.965 (9.671)	169.905 (8.16)	0.128	/	
	MMSE	27.593 (1.647)	27.926 (2.037)	> 27	0.418	/	
	Disease duration (years)	16.185 (6.349)	3.083 (3.499)	/	**< 0.001*** **	**PD+FOG > PD-FOG**	
	UPDRS III (Med ON)	24.222 (12.011)	19.893 (7.125)	/	0.194	/	
	FOGQ	13.815 (4.17)	/	/	/	/	
	FOG trajectory – Med ON	6.652 (8.663)	/	/	/	/	
Prior to APA	**AP COP position (% of foot length)**	56.875 (7.693)	53.794 (10.936)	56.229 (10.457)	NS (0.306)	/	**PD+FOG > PD-FOG** (0.002**)
	ML COP position (% of stance width)	54.383 (6.142)	53.328 (9.512)	48.34 (4.208)	**0.007****	**PD+FOG > HC** (0.011*) **PD-FOG > HC** (0.026*)	NS (0.621)
	Stance width (mm)	278.432 (46.221)	248.716 (41.207)	262.572 (42.164)	**0.041***	**PD+FOG > PD-FOG** (0.031*)	NS (0.293)
During APA	**AP size of APA (mm)**	27.117 (22.179)	40.95 (23.805)	51.678 (23.325)	**< 0.001*** **	PD+FOG < PD-FOG (0.019*) **PD+FOG < HC** (< 0.001***)	NS (0.568)

	ML size of APA (mm)	23.475 (18.676)	24.013 (16.576)	28.87 (16.538)	NS (0.202)	/	NS (0.534)
	APA duration (s)	0.872 (0.288)	0.8 (0.3)	0.656 (0.253)	NS (0.085)	/	NS (0.699)
	Lateral COP shift during unloading phase (mm)	109.661 (42.321)	86.828 (32.847)	110.674 (38.173)	NS (0.076)	/	NS (0.38)
	Unloading phase duration (s)	0.485 (0.182)	0.326 (0.115)	0.317 (0.141)	**< 0.001*** **	PD+FOG > PD-FOG (< 0.001***) **PD+FOG > HC** (< 0.001***)	NS (0.058)
First step	**Swing phase duration (s)**	0.548 (0.114)	0.517 (0.08)	0.502 (0.075)	0.19	/	NS (0.88)
	First step length (m)	0.511 (0.17)	0.603 (0.113)	0.643 (0.095)	**< 0.001*** **	PD+FOG < PD-FOG (0.012*) **PD+FOG < HC** (< 0.001***)	NS (0.549)
	First step velocity (m/s)	0.979 (0.374)	1.211 (0.335)	1.314 (0.256)	**< 0.001 *** **	PD+FOG < PD-FOG (0.016*) **PD+FOG < HC** (< 0.001***)	NS (0.548)

Figure 2

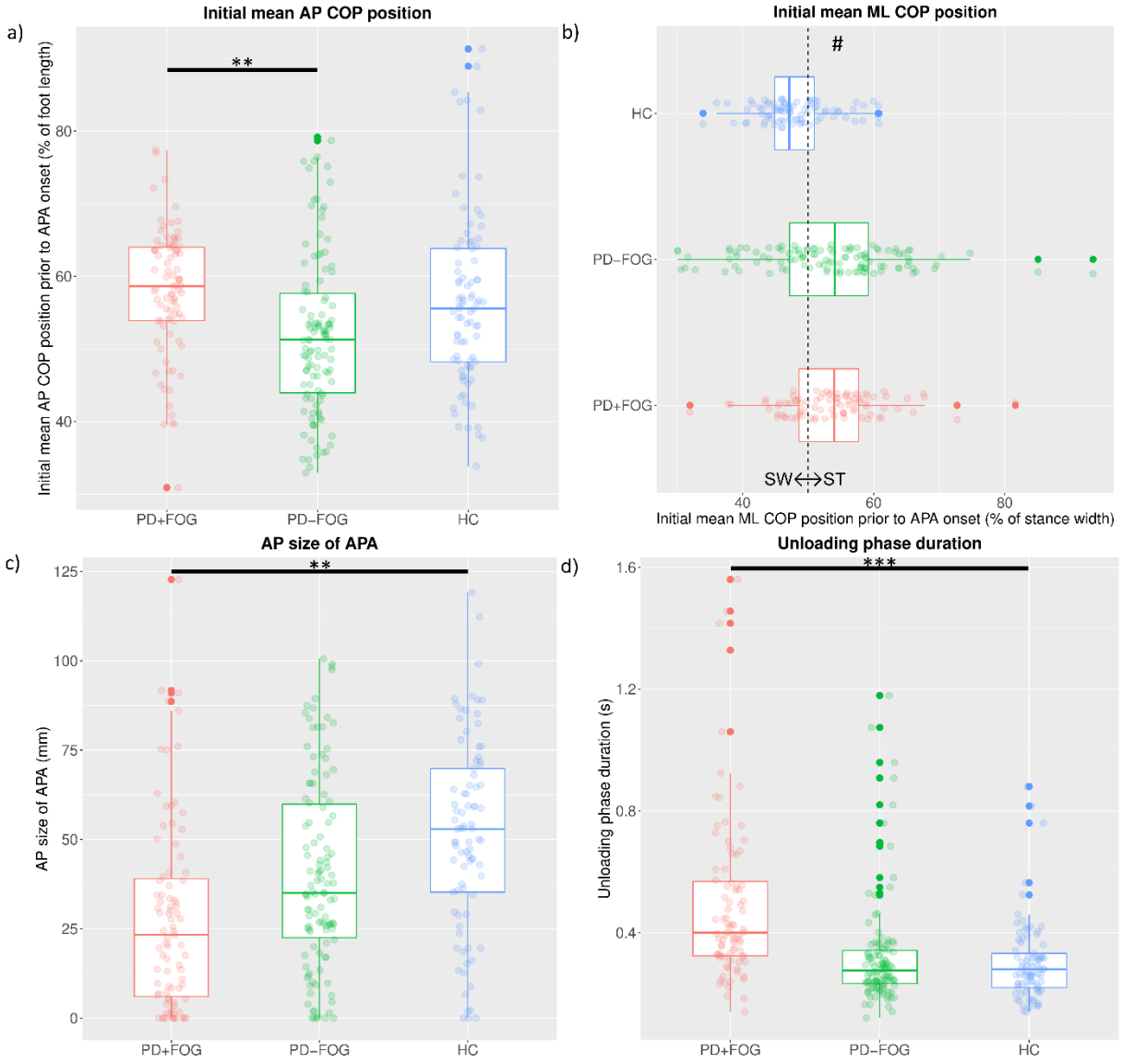
a)
Initial mean AP COP position
**
Initial mean AP COP position prior to APA onset (% of foot length)
80
60
40
PD+FOG
PD−FOG
HC
b)
Initial mean ML COP position
#
HC
PD−FOG
PD+FOG
SW⟷ST
40
60
80
Initial mean ML COP position prior to APA onset (% of stance width)
c)
AP size of APA
**
AP size of APA (mm)
125
100
75
50
25
0
PD+FOG
PD−FOG
HC
d)
Unloading phase duration
***
Unloading phase duration (s)
1.6
1.2
0.8
0.4
PD+FOG
PD−FOG
HC

Table 2

Dependent variable	Group	Best model	Standardized regression coefficients	p-values	AIC	BIC	logLik	Conditional R2	Marginal R2
1ST STEP LENGTH	**PD+FOG**	**~ AP COP position**	**-0.138****	0.005	1015.218	1029.944	-501.609	0.926	0.068
		+ ML COP position	**-0.129***	0.015					
		+ stance width	**0.179***	0.011					
	PD-FOG	**~ AP COP position**	**-0.213***	0.029	1301.537	1323.426	-642.768	0.768	0.249
		+ AP size of APA	**0.201****	0.007					
		+ COP_U	**0.231****	0.002					
		+ T_U	-0.091	0.092					
		+ disease duration	-0.215	0.121					
	HC	~ APA duration	-0.137	0.09	992.862	1007.518	-490.431	0.703	0.099
		+ T_U	0.181*	0.041					
		+ stance width	0.189	0.12					
1ST STEP VELOCITY	**PD+FOG**	**~ AP COP position**	**-0.114***	0.039	1157.477	1174.658	-571.739	0.886	0.161
		+ ML COP position	**-0.191****	0.001					
		+ AP size of APA	**0.171****	0.007					
		+ stance width	**0.201****	0.008					
	PD-FOG	**~ AP size of APA**	**0.227*****	< 0.001	1514.989	1531.406	-751.494	0.83	0.21
		+ COP_U	**0.236*****	< 0.001					
		+ T_U	**-0.12***	0.011					
	HC	**~ AP size of APA**	**0.241***	0.015	1172.152	1184.365	-581.076	0.535	0.103
		+ COP_U	0.17	0.135					